EARLY DEVELOPMENT AND STABILIZATION OF THE WHITEHEAD TORPEDO

Rani razvoj i stabilizacija Whiteheadova torpeda

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Summary

In the face of a superior French fleet which harassed the Northern Adriatic and the Quarnero in 1859 the Austrian chemist / mechanic Franz Pfeifer proposed the idea of an unmanned littoral explosive boat to the Austrian admirality. This was realized in 1864 by the Imperial-Royal Commander (k.k. Fregattenkapitän) Giovanni Luppis (1813 – 1875), a native of Fiume (Rijeka), who built a model of an automotive (spring- driven), line-guided explosive boat – the "Salvacoste". Due to inherent design deficiencies the Austrian naval authorities requested the ingenious English engineer and industrialist Robert Whitehead (1823 – 1905) in Fiume, where his company STF was employed on government contracts, to cooperate with Luppis.1866 the resulting weapon the "Whitehead fish-torpedo"- differed considerably to the dismay of Luppis from his original concept It was a fully submersible, automotive, and stealth weapon, conceived to deliver a lethal punch into the soft belly of an enemy ship. Depth was at first erratic but later regulated by an improved hydrostatic device the: "Whitehead's Secret". Lateral stabilization via launching tube and fins still proved inadequate at longer range, though 1872 uni-axially counter-rotating propellers improved the situation.
The torpedo revolutionized naval warfare: novel ship. types and –building, naval thought and tactics were affected. No patents were applied for protection of this invention and the k.k. Marine waived any priority claims. Thus torpedoes were sold as well as licences for manufacturing to all navies of the world. The main business went to Fiume's Whitehead facilities and this striving / thriving city became the cradle of the torpedo. Nevertheless the Austro-Hungarian Navy lost an edge in technological superiority over its potential future adversaries for many years.

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In 1894 the Triestine Ludwig Obry (1852 – 1942), a naval designer, patented his ingenious "Geradlaufsteuerung", in which he applied and refined Foucault's (1819 – 1868) principle of the gyroscope to the navigational guidance of the torpedo, thus also stabilizing laterally the course of the torpedo to its target. The gyroscope uses the fact, that a rapidly spinning rotor is retaining its axis unperturbed, even if its mount is disturbed directionally.

Again this caused a revolution in naval warfare and splendid business for the entire region of Fiume (Rijeka). The preset course of the torpedo made it independent of launching and maritime disturbances, therefore high precision / stealth hits – depth-wise and laterally – could be obtained at longer ranges. Guided missile and modern torpedo led after WWII eventually to the eclipse of the big-gun / heavy armoured ship.

The torpedo with all its instruments, mechanisms, sensors, devices and propulsion constituted not only the most formidable weapon at sea but also the most complex mechanical system of the 19th century. Even today the overall design has hardly been changed. Modern technological progress has enhanced warheads, sensors, devices, propulsion, and launch resulting in greater hit probability and lethality at higher speed and longer range.

The evolution of Obry's gyroscope still shows a tremendous impact on all technical means and vehicles, which have to rely on motion and a stabilized course in a perturbed environment such as water, air, space or rugged terrain. An example is the gyrocompass.

On the other hand with torpedo development and business declining, the industrial facilities at Rijeka could not be maintained any longer. Rijeka's torpedo plant, cradle of the torpedo and a center of engineering enterprise, has been dismantled to a ruinous state and has now become a site for industrial archaeology.

1. INTRODUCTION

No other weapon has undergone so little change in its composition and appearance within the past 140 years and none has so much influenced naval thought and warfare in the last century, as has done the torpedo. Due to its comparatively low cost, its relatively simple launching device, its stealth course, its high accuracy and lethality, it has revolutionized naval thought and warship. construction. Also Austria-Hungary – then a major European land- and sea-power - was affected as the country of its origin.

The torpedo always from its beginning on represented in its components the limits of existing technologies. The torpedo first having been launched from ashore and ship. found in the submarine the ideal carrier, the aircraft still increased its range, and the missile did so further thus achieving its ubiquity.

Fiume – Rijeka – has been the cradle of the torpedo. This ambitious port with a thriving industry and its industrious, multi-ethnic population has "hatched" the torpedo for over a century. Today only ruinous plant halls and the rotten structure of the torpedo-launching pad remind as symbols of its great past but also of possibilities still ahead!

2. THE TORPEDO AND ITS NAVIGATIONAL CONTROL

2.1. The Torpedo and its History

2.1.1. A Brief History of the Torpedo [2,7,16,45]

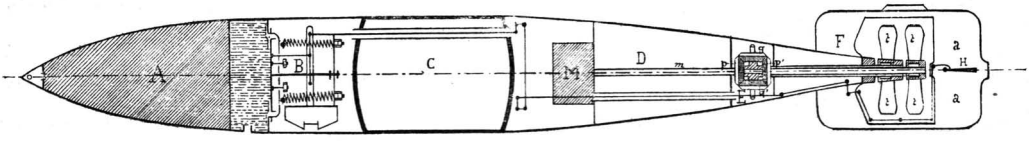
At the beginning was the wind / water current- driven fireship. (brulotto) during the times of classic sea-warfare:

- 1776 David Bushnell (1742 – 1824), USA, designed the "Turtle", performed submarine experiments, and realized the effect of the subaquatic explosion [25]
- 1801–05 Robert Fulton (1765 – 1815), USA, designed the first submarine "Nautilus" and a drift mine
- 1846 C.F. Schönbein (1799 – 1868), Germany, invented the gun cotton
- 1861 U.S. Patent Nr. 33940 by Pascal Plant for a rocket-propelled torpedo
- 1861–65 During the US Civil War came the advent of the "spar torpedo" (s. fig. 14) [13]
- 1864–67 Luppis (1818 – 1875), Fiume, and Whitehead (1823 – 1905), UK, developed the "Fish Torpedo"
- 1868 Whitehead improved the hydrostatic valve precision through a pendulum actuator
- 1871 John Adam Howell, USA, developed a flywheel-driven torpedo, twin screwed, which was the first torpedo to prove itself laterally stable
- 1873 Thorsten Nordenfelt, Sweden, built the first battery-driven torpedo which travelled a distance of 2 miles at 10 kn
- 1875 Alfred Nobel (1833 – 1896), Sweden, invented the "Dynamite"
- 1895 Ludwig Obry (1852 – 1942), Trieste, applied his Gyroscope to the Whitehead torpedo for lateral control and stabilization.

2.1.1. A Description of the Torpedo [11,14]

The torpedo is a cigar shaped submarine missile (s. fig. 2), automotive and with automatic control in two planes, being launched by submarine and surface vessels, from aircraft and littoral emplacements. The hull is today of rustproof metal – stainless steel was invented only after 1912. Its length varies between 6 – 9 m, its outer diameter (calibre) is between 14" to 24". According to its propulsion we distinguish: gas-, steam-, electric- and reactive powered torpedoes.

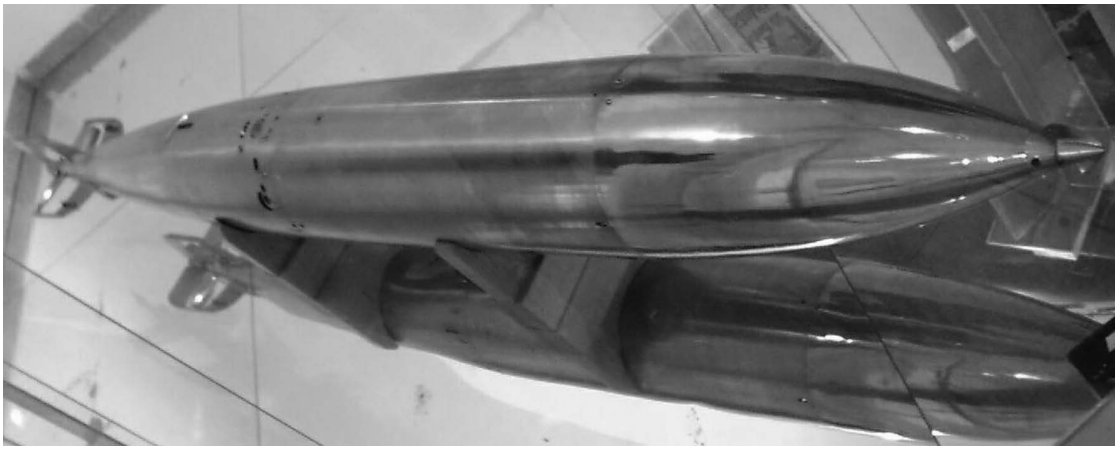
A modern torpedo contains complicated instruments and devices, which control its depth and direction in accord with its preset course or after signals acquired through remote control, or from an external source, as well a mechanism (ignition chain), which detonates the explosive warhead, when it



Coupe schématique d'une torpille Whitehead, montrant les divers compartiments.

A, cône de charge. — B, compartiments des régulateurs. — C, réservoir d'air. — D, flotteur. — E, emplacement des engrenages. — F, queue. — H. gouvernail. — M, machine. — *tttt*, hélice. — *aaa*, ailerons.

■ *A French Whitehead torpedo at about 1895* [19]



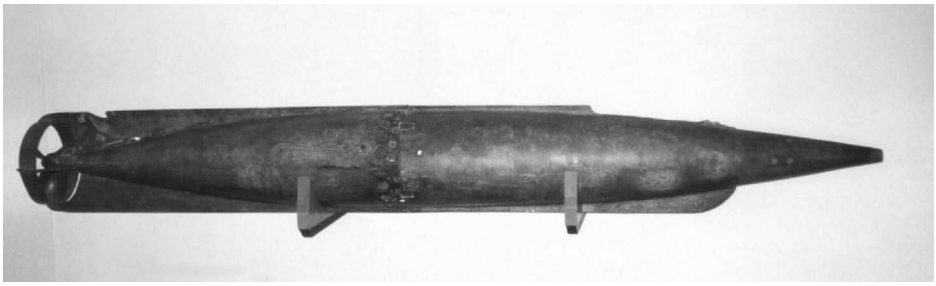
■ *A Whitehead torpedo, as used by the k.u.k. Kriegsmarine during WW I from the Army Historical Museum (HGM), Vienna*

approaches or strikes the target. The hereby released sub-aquatic explosion causes damage or destruction of the target. (s. Annex 3) We distinguish according to its track: straight running, manœuvering and self homing torpedoes [14].

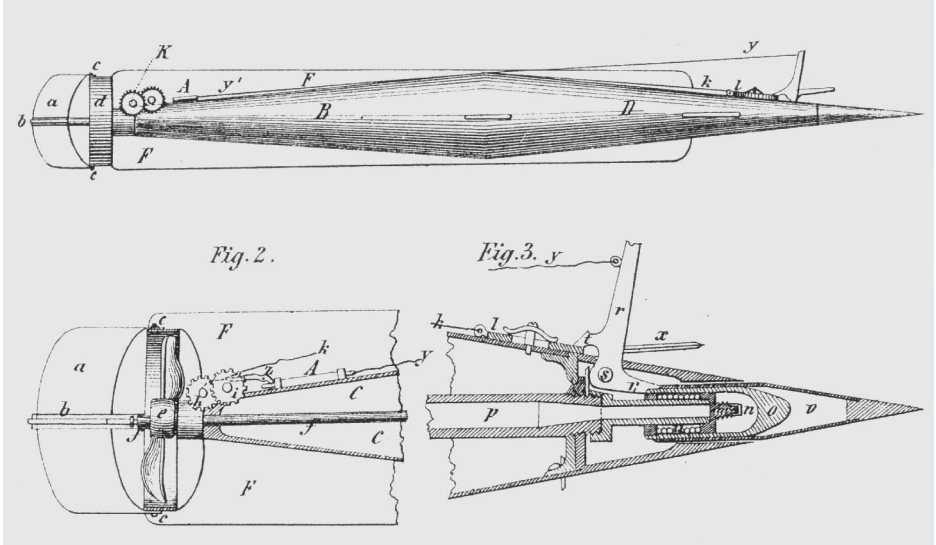
The torpedoes construction has to be functional, with a minimum of hydrodynamic resistance, watertight and corrosion proof, optimal in lightweight construction (function / displacement / space / weight / strength) and accurate. A large contact area is required as well as a reliable ignition chain.

In 1898 the torpedo consisted essentially of 6 major compartments interconnected by longitudinal and transverse bolts [32] and which were arranged in various configurations within the stern:

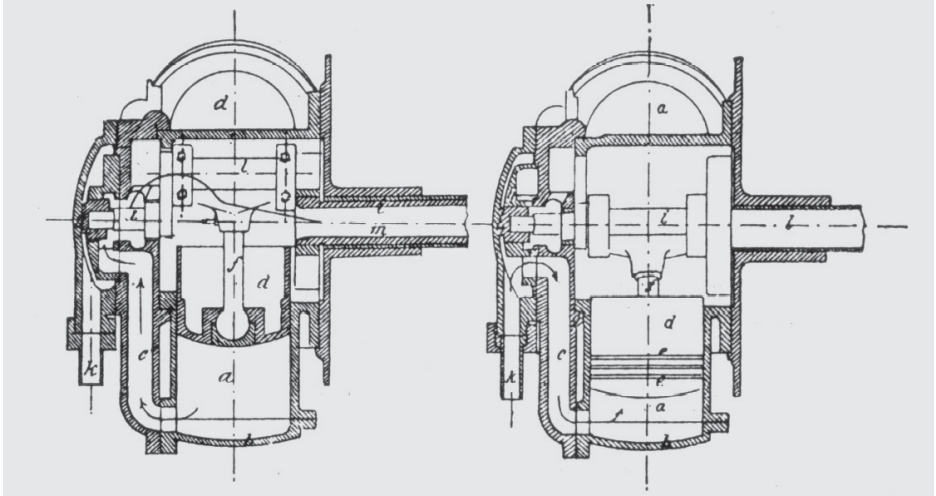
1. Warhead with percussion fuse and ignition chain, safe-and-arm device, and explosive charge. It is watertight and dismountable.



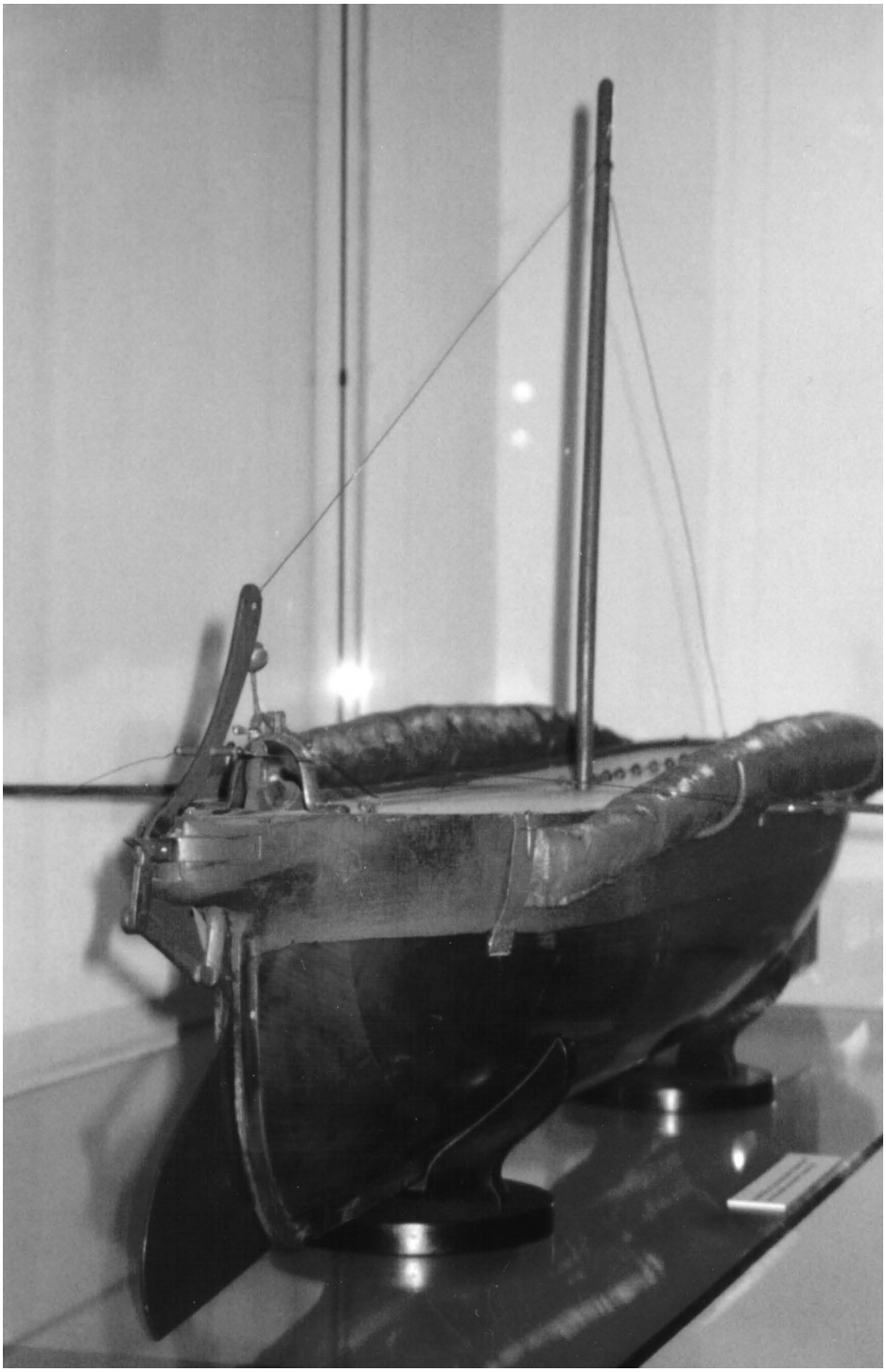
■ *Luppis – Whitehead fish torpedo from the Army Historical Museum, Vienna*



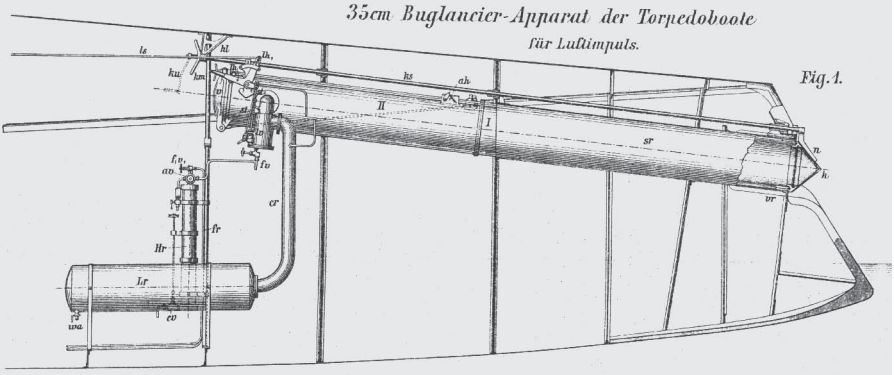
■ *Depiction of the early Luppis- Whitehead torpedo* [2]



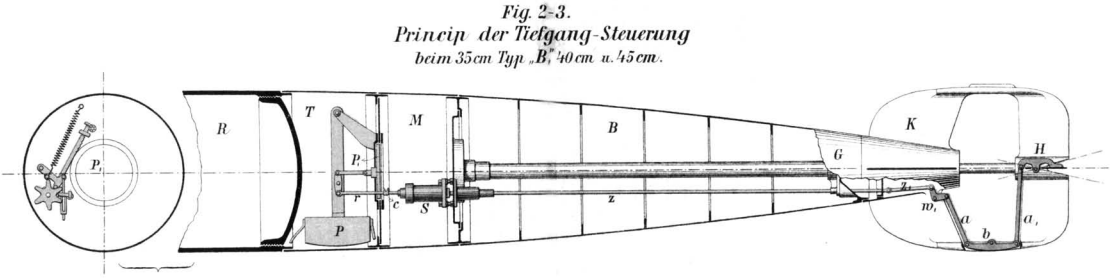
■ *Two-cylinder sleeve valve operated compound engine* [42]



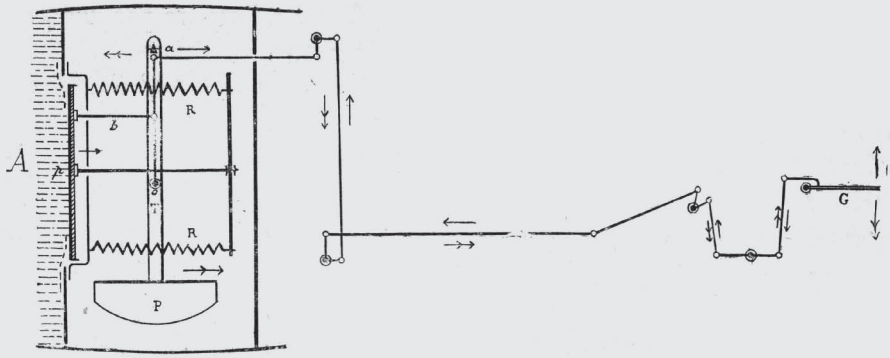
■ *Luppis' "coast saviour" (salva coste) as a model at the Army Historical Museum, Vienna*



■ *The bow starboard torpedo launching tube of the k.u.k. torpedo-boats XXVII – XXXII, 1886* [44]



■ *The depth regulation device from Whitehead* [44]



Régulateurs et leur mode d'action.

p, piston hydrostatique. — *b*, bielle. — R R, ressorts antagonistes. — A, point de suspension du pendule. — P, pendule. — T, tige du pendule. — G, gouvernail.

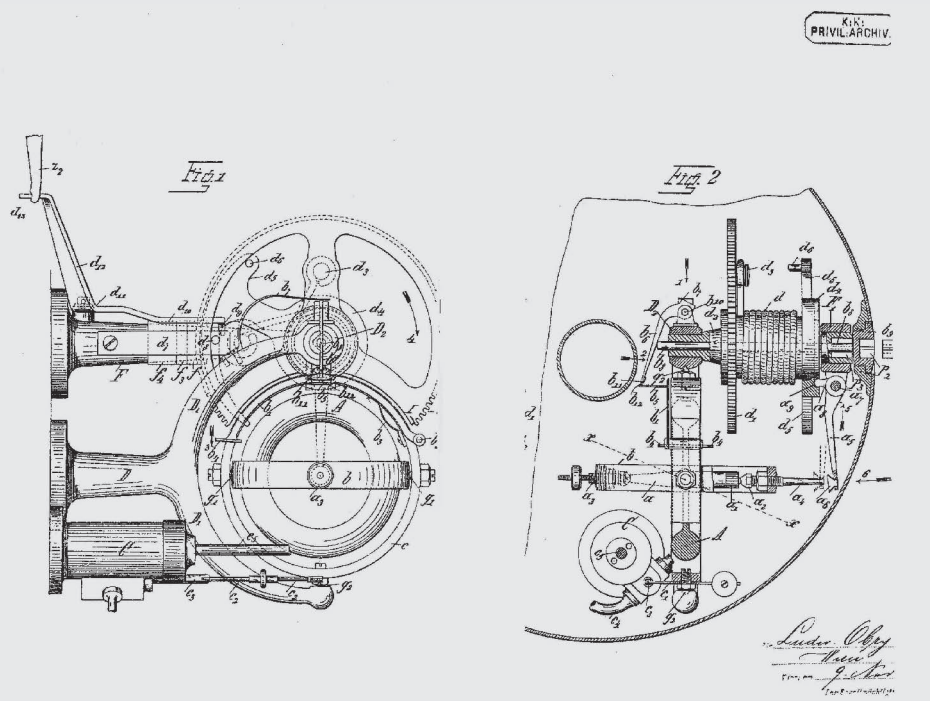
■ *The mechanism of the depth regulator* [19]

2. Gas-pressurized container with air or gas filling at originally 25 atm pressure – 1902 already at 150 atm – this constituted as well the potential in range and speed (s. Annex 2)
3. Depth chamber fixed to 2), contained the valves, water- and fuel tanks, depth control – later shifted to section 5), transmission gears and / or servomotor to the elevator fins
4. Propulsion compartment with main drive and servo motors, pressure distribution valves, and propeller shaft; not watertight, and formed with the following section the:
5. Balance chamber the so called "tunnel part", which contains the gyroscope. It is waterproof through a bulkhead towards section 4) with transmission shafts towards the:
6. Tail, which houses the ballast tank – for reserve buoyancy, the rigid stabilizing fins, the elevator- and the directional flaps and the propellers with their gear.

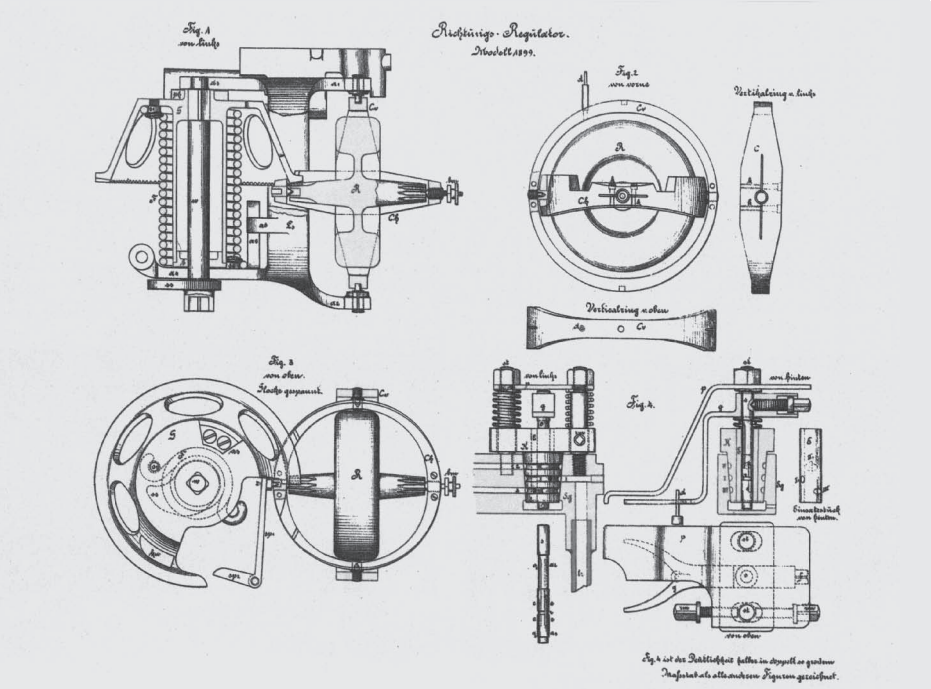
2.2. The Navigational Control [11,41]

2.2.1. A Brief History of Gyroscopic Stabilization and Control

- Geronimo Cardano (1501 – 1576), mathematician, invented the "cardan" suspension
- 1629 – 1669 Balthasar Rössler (1605 – 1673) devised a cardan suspended compass for surveying
- 1852 Leon Foucault (1819 – 1868), France, proposed the first gyroscopic compass
- 1877 Edward J. Routh, (UK), developed a criterion for determining stability (Routh – Hurwitz criterion)
- 1892 Oliver Heavyside (1850 – 1925), UK, and A.M. Lyaponow (1857 – 1918), Russia, studied the stability of non linear differential equations
- 1894 Ludwig Obry, Trieste, applied his patent for lateral stabilization of the preset torpedo course
- 1898 Nicola Tesla (1856 – 1943), Zara, built the first propeller driven radio--controlled boat
- 1908 H. Anschütz- Kämpfer (1872 – 1931), Germany, developed the first practical gyroscopic compass
- 1909 – 11 Elmer A. Sperry (1860 – 1930), USA, improved the Anschütz design
- 1910 Elmer Sperry invented a gyro for stabilization and ship. control
- 1912 his son Lawrence Sperry invented the airplane autopilot



■ *The gyroscope of Obry from his patent 1894* [36]



■ *The gyroscope / direction regulator* [44] *1899, with spiral spring drive*

2.2.2. The Depth Keeping Device > "Whitehead's Secret" [10,40]

This device consists of a hydraulic piston on which the outside water is exerting pressure, which from the inside is reacted by an adjusted spring for a pre-determined depth.

Does the torpedo descend deeper than the pre-tensioned spring would allow, then the excessive water pressure pushes the piston inwards – the elevator is tilted upwards and affects a rise of the torpedo.

Is the trajectory of the torpedo too flat then the spring pressure exceeds that of the ambient and pushes the piston outside, the elevator is tilted downwards and affects a descent of the missile.

The original depth regulator – a hydrostatic valve – proved unreliable at low depth, so Whitehead solved this problem himself in 1868 > "Whitehead's secret".

The movement of the piston is now transferred to the sliding valve of the steering machine through employment of a pendulum as an actuator, which has to control the movement of the depth pressure piston.

Is the torpedo in descending situation, then the pendulum swings forward and moves the elevator upwards. Is the torpedo in ascent then the pendulum swings backwards and tilts the elevator downwards.

The action of the pendulum is always exceeding. The combined movement of piston and pendulum is transferred via a system of rods and levers to the steering machine, which is driven by compressed air, and from there to the elevator, allowing only a vertical deviation of 15 cm at 400 m distance.

At launch the pendulum has to be arrested and is activated once a horizontal position is obtained.

2.2.3. The Directional Apparatus – System "Obry" [31,34,39,41]

The tail of the torpedo accommodates beside the depth control regulator also the directional control device. Already in 1890 Whitehead had collaborated with the Russian engineer Petrovich on a crude gyroscope with two rectangular gimbals and had therefore rejected Obry's offer in 1894. So Obry turned to the Italian Naval Minister Benedetto Brin in support for his development in1895, his patent of the gyroscope in Italy had been applied already in Dec. 1894. On Jan. 25th 1897 Whitehead finally bought Obry's patent. Essentially the invention constituted a refinement of Foucault's gyro and consisted of a 800 g heavy flywheel of Ø 7 – 8 cm, the axis of which was suspended by a cardan joint, parallel to the torpedo axis in non-operational state [16,28,36].

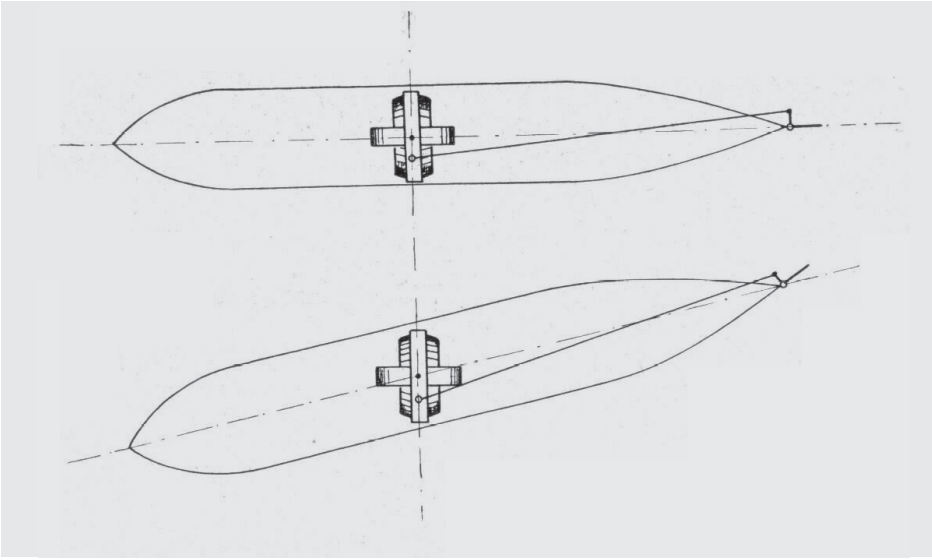
The components of Obry's direction regulator consisted in general of a measuring circuit: made up. from the cardan suspended flywheel, its driving

system and its adjusting / locking device and of the control circuit: steered by the gyroscope via transmission links towards the pair of rudders.

The spiral spring drive, which is attached to a toothed wheel and in gearing contact with the likewise toothed ends of the flywheel's axle, is retained by an angular lever at zero-position. At launch the pre-tensioned spring is released and sets the flywheel spinning at 2400 rpm. The ensuing moment of ~ 3 kgm is transmitted via a pin, attached to the vertical (outside) gimbal and extending slightly off-centre, and which is encompassed by a crank activating the sleeve of a two-way valve, mounted to the support structure.

If by exterior or interior disturbance the torpedo is forced to deviate from its preset course, then the position of the gyroscope within the torpedo is changed. Then the pin would be activated to left and right by the flywheel, as it tends to retain the position of its spinning axis – even when the torpedo is heeling over. The two-way valve passes a proportionate quantity of air to the steering engine in order to counter- act any course deviation. The piston rod itself is connected to a linkage tilting the lateral rudders oppositely to starboard and port to re-establish its course.

In practice each rudder position represents an end-position: port – starboard – port – a.s.o. with a maximum amplitude of 2 m on a 2000 m run of the torpedo giving the impression of a serpentine – similar to the chart of a damped vibration – representing the original rotation plane of the gyro [32,33,34].



■ *The functioning principle of the gyroscope [32]*

The gyroscope exacts an indirect control as it only serves to register any lateral deviation from a preset course and does not apply directly any corrective measures to the lateral rudders. Thanks to Obry's directional regulator the torpedo achieved an accuracy of ½ ° at 7000 m distance, though the torpedoes operational range was about 1000 m then. The range, accuracy, and submarine explosive effect had already surpassed by then that of the heavy artillery of capital ships. Also the torpedo-boat tactics were effected to a high degree, as a target distance of > 400 m became possible and a preset angle of 90° could be realized. The only disadvantage was at that time the decrease in revolutions of the spring driven gyroscope on longer distances and therewith its diminishing force in transferring the tilt to the lateral stabilizing fins. 1910 that problem was overcome by introducing an air-jet driven flywheel, which could spin almost indefinitely.

3. THE STORY OF ITS ORIGIN [24,30,40]

3.1. The Historical Background and Development

During the Austrian – French War of 1859 the French Fleet could operate virtually unopposed in the Adriatic. Venice, Trieste and the Croatian coast were prepared for defence and the harbours were mined for the first time. In June 1859 the French fleet even made landfall in the Quarnero, on Lussin and in Fiume (Rijeka) [15,27]. Under that impression of impotence of the Austrian Navy Franz Pfeifer, a chemist and mechanic, proposed to the Austrian commander in chief of the Adriatic war theatre FZM Graf Gyulai [43] to construct a buoyant vessel consisting of two longitudinally joined cylinders with end-cones. The first cylinder was to be filled with pressurized air for propeller propulsion and the second with explosives, igniting at impact with the target by a percussion fuse.

1860 Fkpt. Johann Blasius Luppis, commander of the k.k. frigate "Bellona" had on board [8,9] a model of the "salva coste" constructed. It was an entirely tarpaulin-covered boat of approximately 6 m length, driven by a clockwork propelled ship-screw. It had two rudders, which controlled and guided the vessel by lines from ashore towards the target (s. fig 4). In its hold it carried an explosive load, which was to be detonated underwater by percussion fuses, fixed to 4 poles when hitting the target ship. Because of lack of a suitable steam-engine a clockwork was installed – a great mistake! 1864 Luppis proposed his invention to the KM / MS and requested funds for further development. Despite presentation of the model in the presence of Emperor Francis Joseph, though the potential was acknowledged, it was rejected for financial reasons and doubts on the feasibility of the system [4].

The proprietor of Stabilimento Tecnico Fiumano (SFT), the English engineer Robert Whitehead dedicated himself upon intervention of the KM and

mediation of the Fiuman business man Giovanni di Ciotta to the invention. He realized the apparent deficiencies and developed / invented from Luppis idea the "Fishtorpedo", whereby he actually approached closest the original concept of Franz Pfeifer. He rejected the proposed surface run – because of interfering swell and visibility – in favour of a submarine course, the depth of which was regulated by a hydrostatic valve. The line control of the rudder – the only thing still reminding of Luppis basic idea – got entangled hopelessly in the propeller, so it was eventually replaced by a trimmed rudder and guidance through the launching tube. Propulsion of the two-bladed screw was by a two-cylinder oscillating air pressure motor. (s. Annex 1)

On Dec. 20th 1866 a fish-torpedo was launched from 370 m distance in the presence of a commission consisting of Archduke Leopold and Fkpt. von Littrow. The presentation was imposing and despite some teething troubles: promising! On April 15th and May 20th 1867 a contract between the KM / MS and both inventors was concluded, which assigned in case of success an award of 200 000 Gulden to the latter, as well the right to sell their invention to third parties. Towards the end of 1867 Whitehead invented a fixed underwater launching tube which had been installed in the old gun-boat "Gemse" below its waterline [4]. The torpedo was introduced into a chamber and locked out hermetically. At opening of the outside port the torpedo was ejected by an air-pressure driven piston, whereby it was led over a protruding tappet, which started various delayed action mechanisms within the missile.

The current tests showed, that the hydrostatic depth regulator was inadequate. Whitehead installed his "secret", in which he augmented the depth regulator by a heavy pendulum, which over a leverage system to the elevator countered any inclination.

At a test series on July 12th 1867 from 28 launchings at 670 m distance 12 absolute failures stood against 16 hits within a 200' long target net, simulating the size of a gunboat, i.e. 57 % were on target. Target and launching tube were anchor-secured. Whitehead could prove now, that the depth aberration lay within ± 15 cm! Accuracy, range and effect filled the k.k. Navy with enthusiasm, while at a range of beyond 400 m the deviation and the speed of the missile would still prove inadequate for a naval engagement.

On Aug. 27th and 28th 1868 Whitehead delivered after conclusion of the commissioned tests one Ø 35 cm (14") and one Ø 40 cm (16") "standard torpedo" with drawing sets to the k.u.k.- Kriegsmarine. With this event the contract conditions between Luppis and Whitehead had expired and their relationship. had markedly disimproved. After impressive presentations for the British Admiralty in Sheerness [16a] great Britain acquired the torpedo in February 1871. Though the Royal Navy had initially rejected this novel weapon as hideous and unworthy ("....a damned un-English weapon!"), it recognized

the general trend and a torpedo workshop. was immediately founded at Woolwich Arsenal. That was the break-through for the torpedo! France followed in 1872, Italy and Germany in 1873. Scandinavia 1875, Turkey and Russia 1876, and by 1877 the rest of the world, Japan and the USA included, had acquired the torpedo. Each national improvement of the torpedo was immediately forwarded and applied internationally. So the contra-rotating propellers developed in Woolwich increased the speed from 7 to 12 kn and prevented rotation about the torpedo's axis, also enhancing course stability and range.

1872 progress in technology and material sciences brought further improvement for the torpedo in speed, range, and higher explosive effect. A 3-cylinder Brotherhood engine fed from a stronger pressure vessel became standard equipment. The displacement increased from originally 136 to 240 kg.

Whitehead was successful, he bought the SFT in Fiume and founded the Silurficio Whitehead. Still his "secret" of the depth control device [6,7] had been kept.

- 1875 surface launch of the torpedo by the Royal Navy
- 1877 the calibre of Ø 16" was reduced to Ø 14" by the Royal Laboratories
- 1883 Dr. R.E. Froude from the laboratories of Torquay discovered the improved hydro-dynamically ogival nose form, which allowed a greater explosive charge and contact surface.
- 1890 The torpedo head became spherical (since 1980 it has a stubby form!) and the R.N. introduced the Ø 18 " torpedo.
- 1894 Fiume produced 900 torpedoes annually
- 1895 The lateral directional control apparatus of Obry was adapted by the engineer von Petravic for Whitehead. In general it was a precision gyroscope, which governed via leverage or servo motor the lateral rudders, which became standard outfit in...
- 1898 For a theoretic range of 7 km the deviation could be smothered by ½°. Even the enormous heel at athwart launch could be compensated, thus increasing the range to 4 km.

A further increase in performance / speed was achieved through the torpedo-heating in 1901 and was introduced in 1904 / 5, which also prevented icing at low environmental temperatures. Whitehead, England, developed a preheating and enrichment of compressed air by a mixture produced in a generator from through a nozzle burnt oil and overheated water vapour. (s. Annex 2)

By then range and target accuracy of the torpedo had equalled that of the heavy naval ordnance, the effect of the underwater explosion having even surpassed it by far. By means of the submarine it was the first operational stealth weapon for always and for everywhere.

3.2.1. The Whitehead Fishtorpedo [6,16,22,40,42]

The first Whitehead Torpedo was a spindle-shaped body made from riveted steel sheet of 3.4 m length, Ø 36 cm max diameter and a total displacement of 136 kg. It had in its longitudinal plane a guidance fin on top. and below, which protruded by 2.5 cm and which passed sternwards to support the propeller shroud. In the horizontal central plane two shorter 2.5 cm fins were also protruding. The warhead mounted a simple percussion fuse for an 8 kg explosive charge of compressed gun cotton engulfed by an initiating charge. The depth chamber contained the original form of a depth regulator, then consisting of a membrane encased in a bulkhead, on one side pre-tensioned by a spiral spring to simulate the operational depth and the other exposed to ambient water pressure. Any pressure difference from the normal equilibrium was automatically transmitted by wires to the elevators.

At launch a lever was tilted, which released over a rod assembly the air regulator, activating engine and fuse. The adjoined engine compartment, circulated by seawater for cooling, contained a two-cylinder compressed air-powered Brotherhood engine, which drove by crank a shaft for a two-bladed propeller screw. Each cylinder had a small piston valve casing connected to it by channels, into which the piston valve regulated the air flow for the working cylinder.

Connected to it was a pressure vessel containing air at 25 atmospheres, which was penetrated by the stern-tube engulfing the propeller shaft. The stern compartment contained the buoyancy tank, the adjustable lateral fins, the two-bladed propeller with its shroud, the movable elevator and arresting device to deactivate the missile upon termination of its run. The equilibration of the torpedo was performed by air-filling the tank and additional lead weights. The stern tube with safe-and-arm device released the safety lever after a certain number of revolutions.

(Tempirvorrichtung) via a rod linkage for arming the fuse or – when astray of the target- opened a submergence cock between buoyancy- and engine compartment and for disarming the warhead. The torpedo scuttled itself harmless to the ocean floor.

Two devices were responsible for the accuracy and reliability of the Whitehead torpedo: the depth control and the lateral direction control (s. § 2.2.2).

3.3. A Retrospect [30]

In 1867 Whitehead had concluded a contract with the k.u.k.- Kriegsmarine, which despite successfully performed tests, had waived the exclusive rights to purchase the invention – this would have at least temporarily resulted in achieving a certain superiority as a sea-power. After that all states acquired this

invention, even Austria's potential adversary: Italy, which joined in 1882 the Triple Alliance, thus followed by a period of relative peace [23].

The main components, especially the mechanisms, had been kept a secret from the beginning. Each state, having acquired the production rights, was obliged to guard the secrecy of the drawing set. The torpedo as such never has been patented, because it was feared that after patent disclosure imitation and infringements would carry a serious loss for the native industries [16a,33]. With the German Schwartzkopff – (blackhead!) torpedo, originating later and after mysterious happenings in Fiume (plant intrusion, as well as dismantling of an experimental torpedo), not only an imitation but also unpleasant competition arose in sales, as it even featured a rustproof shell of phosphorous bronze.

3.4. The Influence on Naval Warfare [9,13,30,39]

3.4.1. The New Sea-warfare Scenario [18,22,38,46,47,48]

The torpedo had been recognized by all naval powers as a decisive weapon, as with its launching system it could be easier and cheaper accommodated, and cause greater damage than a heavy gun turret. It seemed so that even unimportant sea-powers could challenge the greatest. France in constant rivalry with Great Britain considered even a torpedo-boat fleet for the future. Small unprotected speedboats with torpedoes as main armament, could attack an essentially stronger victim and thanks to superior speed and low signature easily escape. In order to counter that threat small calibre rapid firing guns were introduced. > The torpedo assailant arrived from single precision shot at an area covering torpedo salvo.

Two fundamental ship. classes and attack forms were developed:

a. The fast torpedo boat with torpedo tubes as main armament and the "hit-and-run" tactics: Sneak approach, fire, and off at top. speed. During WW I this became a well proven tactic of the Italian MAS.

b. The submarine and the underwater attack. Similar as before, but the victim is not even aware of what has happened to it. The submarine became for the torpedo the ideal carrier and owes its existence to the torpedo. Terror ruled the seas!

3.4.2. The Countermeasures

Active: Once gas bubbles disclosed the course of an approaching torpedo outmanoeuvring or firing with automatic weapons usually proved too late. The safest way was to identify the launching platform and to eliminate it, before its eminent attack, for which auxiliary vessels were required:

- against torpedo boats > (torpedo-boat)- destroyers armed with torpedoes and guns
- against submarines > submarine chasers armed with water bombs.

Passive: – torpedo nets made from steel-ring mesh mounted to swivelling spars [14,20] for capital ships at their moorings or anchoring site

- net booms infested with mines for harbour entries
- constructive measures in shipbuilding: longitudinal bulges, to be filled with fuel, double bottoms for capital ships and torpedo bulkheads.

4. APPLICATIONS AND FURTHER DEVELOPMENT [30]

4.1. A Purely Military Purpose

Fascinating is probably less the havoc, which the inconspicuous torpedo carries upon its unsuspecting victim, but this autonomous technical miracle has after 140 years nearly remained unchanged. A torpedo contains all kinds of most modern technology, electronics, sensors and application of energy such as gas pressure, electromagnetism, spring-drive, mechanical transmissions, and mass-acceleration.

The torpedo may be used against surface- or submarine vessels as well as against water constructions. The psychological factor, the terror, which it carries, has forced admiralties to expensive protective measures and to the usage of convoy systems. No civil, peaceful application can be determined in its design potential.

4.2. Applications and Further Development

4.2.1. The Remote-Controlled Explosive Boat [12]

Various patents as f.i. the Sam.– Edison – torpedo 1880, USA, and from Siemens Schuckert 1906, the latter wireless, had been conceived for cable controlled explosive boats.

1916 the Lürssen-yard, Bremen-Vegesack, built wire-controlled "Fernlenkboote" (FL 1 - FL 17), which delivered a 700 kg TNT-charge at 28 –30 kn over a 20 km range. FL 12, -13, FL 15, -16 were controlled by aircraft wireless from Siemens Halske, increasing their autonomy up. to 180 km at top. speed. The participation of Austria – Hungary [12] was cancelled by the German Reichsmarineamt.

During WW II all involved sea powers relied on the manned explosive boat, in which the pilot was supposed to bail out in the final stage of target approach – very often too late! But other modern weapon's systems as f.i. the air-launched torpedo, had already made obsolete Luppis original idea of the wire-controlled explosive boat.

4.2.2. The Modern Torpedo [5,26,35]

The scope: deliver without risk from a safe distance a sufficient explosive charge underneath the keel of an enemy vessel – i.e. without direct physical contact.(s. Annex 3) Once launched, the modern torpedo acquires its target and steers against it automatically until it hits. For that purpose it has all target acquisition devices of active and passive means, as well a proximity fuse. The warhead has today an HE -, SC – or nuclear charge. The torpedo is nearly trace – and soundless in its approach and is driven by electric – or thermodynamic propulsion with an oxygen reservoir. But also the guided missile (Subroc!) allows a fast ballistic transfer [16a] up. to the dive close to the target in order to cause a sub-aquatic explosion. Standard speeds vary between 50 – 60 kn at 20 sm distance for gas-turbine propulsion. Super cavitous torpedoes may travel inside an artificially generated gas capsule at speeds greater than 200 kn! Today's countermeasures do not only concentrate against the launching platform, but are based on the super cavity anti-torpedo torpedo, a development of Penn State Applied Research Lab.

As passive measures the catamaran hull offers due to its negligible immersion of 10 – 15 % versus the normal and its high speed the best protection.

4.2.3. Today's Gyroscope

The evolution of Obry's improved device led to reliable instruments for navigation, air safety and space travel. Everywhere, where stabilization is required because of variable position movement, the gyroscope finds application. This has been achieved on all ships in their navigation control and for roll-yaw stability.

The accuracy of long distance missiles, but also that of the artillery of armoured vehicles, of combat planes (to get tracking), and the gun control of the main armament of warships - it is all based on the effect of the gyroscope. The Austrian Tegetthoff class of battleships could have been the first in the world to be equipped with gyro controlled heavy artillery, had not the k.u.k.- Navy rejected that - despite positive tests! [37]

5. BRIEF BIOGRAPHIES AND APPRECIATION [30]

5.1. Luppis – Whitehead – Obry [1,6,10,11,16]

Fregattenkapitän (Lt. Comm.) Giovanni B. Luppis, Ritter von Rammersdorf (s. fig. 11)

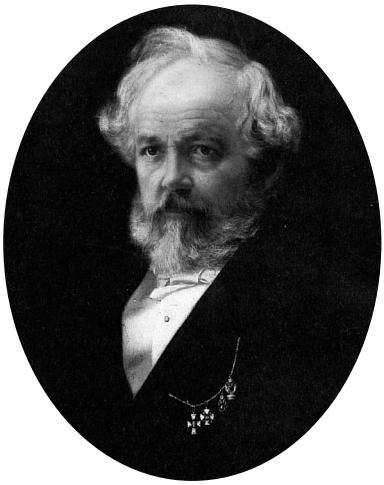
28.1.1818	born in Fiume (Rijeka), his father was a naval captain
1835	he finishes the naval college in Venice
1837	entering the Navy as marine corps cadet
1845	midshipman

Lieutenant Commander Giovanni B. Luppis von Rammer, about 1870, photo from Technical Museum, Vienna

1848	frigate lieutenant
1848 – 1849	participation at the blockade of Venice aboard the frigate SMS "Bellona", where he recognizes the frailty of the Austrian Navy at that time
1851	Naval lieutenant, 1853 Corvette-captain, 1857 Lt. Commander
1859	Commanding officer of the frigate "Venus" before the Dalmatian coast during the Sardo - French War
1860	Chairman of the naval timber yard commission and of the Naval Arsenal, Trieste
1861	demissioned as captain of the "Bellona", obtains the order of the Iron Crown 3rd class, for his invention of the "salva coste"
1864	connection with Robert Whitehead
1866	co-generation of the "Fish-Torpedo", which they present to a Naval Commission
1869	knighted as "Ritter von Rammersdorf"
11.1.1875	dies in Milan, a frustrated old man

5.2. Robert Whitehead, Engineer and Industrialist

3.1.1823	born in Bolton-le-Moors, Lancashire; father was engineer as well
1837	finishes grammar-school, attendance of private school, apprentice at his uncle's company, in spare time he attends and finishes the mechanical institute as an engineer

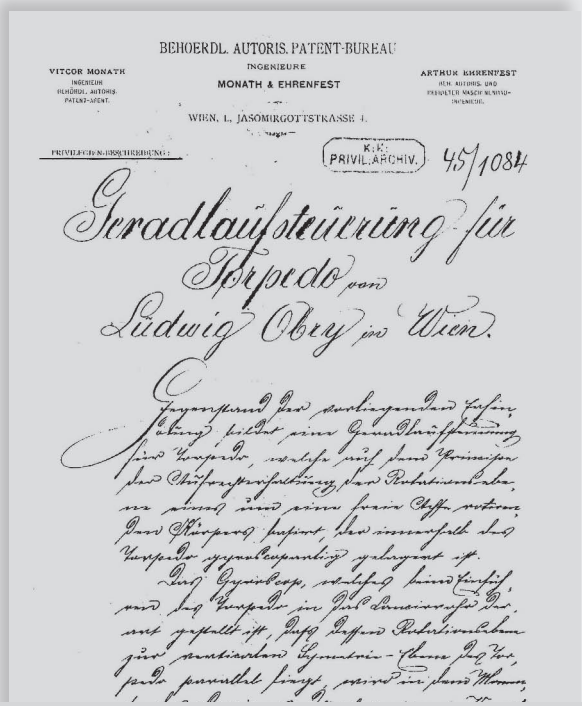


■ *Eng. Robert Whitehead about 1900* [49]

1843	follows his uncle to Marseille and becomes later shipwright in a yard
1847	in Milan, then Austrian, he designs machines for silk manufacture
1849	goes to Trieste as a naval architect at the Lloyd Austriaca
1856	becomes director of the Stabilimento Tecnico Fiumano (STF) in Fiume design and construction of Austrian naval vessels
1864	involvement with torpedo – development
1866	presents the first seaworthy, functional torpedo
1867	devices torpedo launching tube
1868	simultaneously knighted with Luppis to peerage
1873	acquisition of STF and foundation of "Silurificio Fiumano" together with count Hoyos – his later son in law
1876	improvements of the torpedo's course by servo motors
1895	incorporation of Obry's gyroscope for directional control
1905	conversion of his company into an " ltd."
14.11.1905	death in Becket, Berkshire

5.3. Ludwig Obry, Naval Designer, [36,37,49]

22.8.1852	born in Trieste – no trace of any picture of him could be found!
1870	undergraduate at the grammar school in Görz (Gorizia), course in naval architecture in Trieste



BEHOERDL. AUTORIS. PATENT-BUREAU

INGENIEURE

MONATH & EHRENFEST

VITCOR MONATH — INGENIEUR BEHÖRDL. AUTORIS. PATENT-AGENT.

ARTHUR EHRENFEST — BEH. AUTORIS. UND PRIVILEGIERTER MASCHINEN-INGENIEUR.

WIEN, I., JASOMIRGOTTSTRASSE 1.

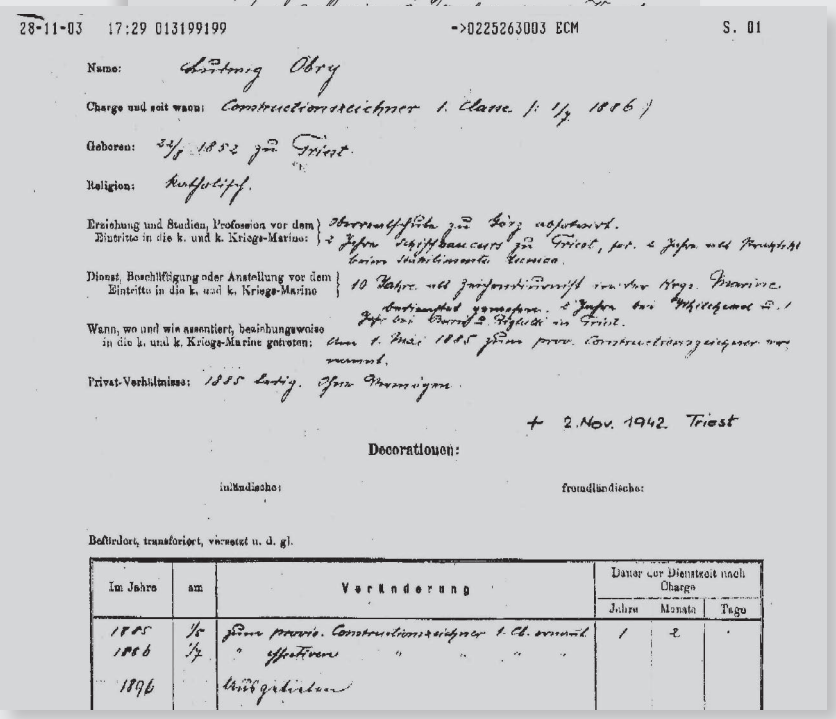
PRIVILEGIEN-BESCHREIBUNG:

K.K. PRIVIL. ARCHIV.

45/1084

Geradlaufsteuerung für Torpedo vom Ludwig Obry in Wien.

■ *Ludwig Obry's record sheet in the k.u.k. naval personnel register [49]*



28-11-03 17:29 013199199 ->0225263003 ECM S. 01

Name: Ludwig Obry

Charge und seit wann: Constructionszeichner 1. Classe (1. 1/7 1886)

Geboren: 24/8 1852 zu Triest.

Religion: Katholisch.

Erziehung und Studien, Profession vor dem Eintritte in die k. und k. Kriegs-Marine: Oberrealschule zu Görz absolvirt. 2 Jahre Schiffbaucurs zu Triest, per. 2 Jahre als Praktikant beim Hafenkommando Venedig.

Dienst, Beschäftigung oder Anstellung vor dem Eintritte in die k. und k. Kriegs-Marine: 10 Jahre als Zeichnerpraktikant unter Kriegs-Marine. Inclusive vorstehende 2 Jahre bei Hafenkommando 2. 1 Jahr bei Werft 2. Rangl. in Triest.

Wann, wo und wie assentiert, beziehungsweise in die k. und k. Kriegs-Marine getreten: Am 1. Mai 1885 zum prov. Constructionszeichner ernannt.

Privat-Verhältnisse: 1885 ledig. Ohne Vermögen.

† 2. Nov. 1942. Triest

Decorationen:

inländische: fremdländische:

Befördert, transferiert, versetzt u. d. gl.

Im Jahre	am	Veränderung	Dauer der Dienstzeit nach Charge		
			Jahre	Monate	Tage
1885	1/5	zum provis. Constructionszeichner 1. Cl. ernannt	1	2	
1886	1/7	" effectiven " " " "			
1896		Hilfsgebühren			

■ *The title page of gyroscope patent: "Geradlaufsteuerung für Torpedos" from Ludwig Obry, Nov. 9th 1894 [36]*

1871	practicant at the Stabilimento Tecnico Triestino (STT), Trieste
1874	draftsman for the Navy for over 10 years
1882	at Whitehead's in Fiume for two years
1883	naval engineering with company Buzzi & Righetti in Trieste (and at SWF?)
1885	"provisional draftsman, 1st class, from his register: "private: unmarried, without any capital" at Arsenale di Pola, 1885 – 1895 with Comitato Tecnico
1886	"effective Draftsman" at section for submarine weaponry
1890	again from his register: "some knowledge in building construction, as well as a capability to carry out easier designs in torpedo-engineering" apparently that sufficed to revolutionize sea-warfare!
1894	invention of GYROSCOPE, patent application: "Privilegium Nr. 1895 / 008564"
1895	Geradlaufsteuerung für Torpedos (directional control of torpedoes)", (s. fig. 13a) and "Privilegium Nr.1895 / 008565 Abfeuern von Geschützen (gun-firing)"
1896	dismission from the k.u.k. Kriegsmarine (Imperial and Royal Navy), designer of gyro- installations at the Viennese mechanical factory of "Ing. Ludwig von Petravic"
2.11.1942	death in Trieste

5.4. From Today's View: an Appreciation [30]

Lt. Com. Giovanni de Luppis realized from naval-tactical considerations an idea of Franz Pfeifer in a model. The latter was surface-bound, was driven by a clockwork, and was wire controlled from ashore. It represented the first remote-controlled explosive boat (and vehicle ?). The ingenious and universal engineer Robert Whitehead, inspired by Luppis and in collaboration with him, developed the autonomous torpedo and its launching device. He recognized the "stealth" – factor for a future submarine attack, which brought the 3rd dimension with it and a galore of design difficulties: Depth- and directional control as well as a lot of launching deviations. Eventually he succeeded in solving all problems in arriving at a fully functional and seaworthy weapon. But only the application of Obry's gyroscope provided the torpedo with that course stabilization which made it independent of all external disturbances and able to hit a moving target with high accuracy and lethal effect.

The combined efforts of all three naval architects led despite many imitations and parallel developments as f.i.: Brennan, Ericsson, and Howell, to the most complex mechanical and weapon's system of the 19th century – differing so

much from its original concept! The war at sea of the 20th century had been greatly effected by the lethality and terror of the torpedo, which in components and appearance has rather remained unchanged up. to date.

6. ABBREVIATIONS AND GLOSSARY [14,48]

6.1. Abbreviations

Fkpt.	Fregattenkapitän – Commander
Lschlt.	Linienschiffsleutnant – Lt. Commander
FZM	Feldzeugmeister, lowest rank of k.u.k. military, corresponding to brigadier
HE	high explosive, f.i.: Hexogen explosive
HC, SC	hollow - or shaped charge
KM / MS	Kriegsministerium / Marinesektion – war ministry / naval section
k. k.	kaiserlich – königlich, – Imperial – Royal, designation before 1867
k.u.k.	Imperial and Royal, the common Austro–Hungarian services after 1867
MAS	motoscafo antisommergibile – speed boat, submarine chaser
WH	warhead
WW I	World War I

6.2. Glossary

Abeam, abreast, athwart: direction vertical to the ship's axis

Gyroscope: is a heavy flywheel in a gimbal mount, which resists torques trying to alter the alignment of the spin – axis and which tends to react to disturbances by precession (slow rotation) in a direction at right angles to the direction of torque.

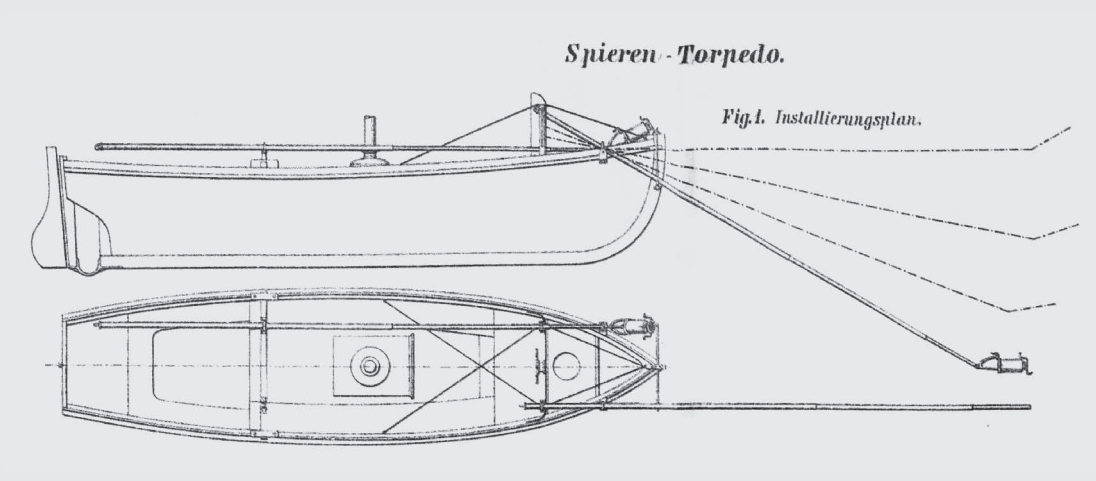
SE, surface effect ships – air cushion craft: vessel with a combined propulsion system, consisting of a lifting- and forward propulsion

Spar torpedo: a 8 -18 m long, extendable pole with a tip. -mounted explosive charge, which was ignited underwater by a lit lunt or electric percussion fuse. This occasion proved at least as dangerous for the aggressor as for the assailed. The first missions occurred during the Civil War and the Russo-Turkish Wear

Speed of sound underwater: 1510 m / s

Stern post: the bordering ends of the torpedo-shell

Stern tube: watertight connecting tube



■ *Spartorpedo boat with two outrigger poles from* [44]

Supercavity: at extremely high speed the torpedo is clad in an artificially produced air bubble, in which it approaches at about 200 kn the target (USNI Proceedings, Sept.2000, Annapolis, MD)

Torpedo: Latin for lameness, electric sting ray. An electric, physical apparatus at both head sides of this fish produces disabling / lethal strokes.

REFERENCES

[1] Heinrich Bayer von Bayersburg: Österreichs Admirale 1867 – 1916; Berglandverlag, Wien 1962, p. 114 / 5.

[2] Karl Beckerhinn: Die unterseeischen Angriffs- und Verteidigungsmittel; Wien 1875 (Österreichisches Staatsarchiv I 59558), p. 4 / 5, p. 39.

[3] Wilhelm Berdrow, u.a.: Buch der Erfindungen; Verlag Otto Spamer, Leipzig 1901, p. 566 – 9.

[4] Franz Bilzer: Die Torpedoboote der k.u.k. Kriegsmarine von 1875 – 1918; H. Weishauptverlag, Graz 1984, p. 9 - 12.

[5] Gen. Editor: Chris Bishop: The Directory of Modern Military Weapons; Greenwich Editions, London 1999, p. 499.

[6] Freg.Kapt. Theodor Braun: Die Kindheit des fünfundsiebzigjährigen Torpedos; Marine. Rundschau; Nov. 1935.

[7] R. Brommy u. H. von Littrow: Die Marine; bearb. von F. von Kronenfels, Hartleben´s Verlag Wien, Pest, Leipzig 1878, 3. Aufl., p. 280 – 9, p. 559.

[8] Antonio Casali & Marina Cattaruzza: Sotto i mari del mondo; Editori Laterza 1990.

[9] Robert L. Connell: Of Arms and Men; Oxford University Press, New York 1989, p. 217, p. 220 –224.

[10] E, M. Cumming: A Short History of Torpedoes 1866 – 1944, Journal of the Royal Navy Scientific Service, Vol. 27, No. 2.

[11] Encyclopædia Britannica CD – ROM, Multimedia Edition, Win 98, 1999.

[12] Harald Fock: Marine Kleinkampfmittel; Köhlers Verlag, Hamburg 1996, p. 95, p. 105.

[13] Gervis Frere-Cook and Kenneth Macksey: The Guinness History of Sea Warfare; Guinness Superlative´s Ltd., Enfield, Middlessex 1975, p. 90-91.

[14] J. Gebauer u. Egon Kreuz: Marine Enzyklopaedie; Brandenburgisches Verlagshaus, Berlin 1994, p. 382-383.

[15] Verlag des k.k. Generalstabes: Der Krieg in Italien 1859; Gerold´s Sohn Wien 1872, Bd. III, p. 169-231.

[16a] Edwin Gray: Die teuflische Waffe; Stalling Maritim, Oldenburg u. Hamburg 1975;

[16b] also: 19th Century Torpedoes and their Inventors; USNI Press, Annap. Md., 2004

[17] Ian V. Hogg: The Guinnness Encyclopædia of Weaponry, Guinness Publishing Ltd.London 1992, p. 96-97, p. 106.

[18] Ian Hogg: The Weapons that Changed the World; Arbor House, New York 1986, p. 68-69.

[19] Lt. de Vaisseau Hourst : Notre Marine de Guerre ; Combet & Cie., Editeurs, Paris 1898, p. 101-122.

[20] William Hovgaard: Modern History of Warships; London 1920, p. 439 and p. 454.

[21] Archer Jones: The Art of War in the Western World; University of Illinois Press, Chicago 1987, p. 426-427.

[22] Peter Kemp. ed: The Oxford Companion to Ships & the Sea; OUP, London 1975, p. 878.

[23] J. W. King: The War- Ships and Navies of the World, 1880 reprint Conway Maritime Press, London 1982, p. 572 – 4, p. 576-577.

[24] Geoff Kirby: Navies in Transition, J.R.N.S.S.; Vol. 27, No. 1.

[25] Prof. B.C. Khoo: Devastating Bubble Power; The National University of Singapore, research work at the Institute of High Performance Computing

[26] Friedrich Lauck: Der Lufttorpedo; Bernard & Gräfe Verlag, München 1981, p. 67, p. 126.

[27] Artur Lengnick u. Robert Freiherr von Klimburg: Unsere Wehrmacht zur See; L.W. Seidel & Sohn, k.u.k. Hofbuchhändler, Wien 1904, p. 85.

[28] Lueger: Lexikon der gesamten Technik; Deutsche Verlagsanstalt, Stuttgart u. Leipzig 1904, Bd.V, p. 689, Bd. VIII, p. 572/2.

[29] Kenneth Macksey: Technology in War; Arms and Armour Press, London 1986, p. 36-38.

[30] Helmut Malnig: Die Entwicklungsgeschichte des Torpedos im Zusammenwirken von Luppis – Whitehead – Obry, Österr. Ing.- u. Arch. Zeitschrift, 149. Jg., Heft 5/2004.

[31] McGraw&Hill Co: Encyclopaedia of Science and Technology, 6th edition, N.Y.,1987, Vol. 8, p. 274-279.

[32] Dr. A. Miethe: Die Technik im 20. Jahrhundert, Bd. VI, Die Technik im Weltkriege, Westermann Verlag, Braunschweig 1921, Obering. Zschorsch: Torpedowesen, p. 243-282.

[33] Mitteilungen aus dem Gebiete des Seewesens; k.u.k. Hydrographisches Amt, Vol. XXIV, Nr. IX, Pola 1896, Karl Gerold´s Sohn in Wien, p. 948-949.

[34] Mitteilungen aus dem Gebiete des Seewesens; k.u.k. Hydrographisches Amt, Band XXVI, Jg. 1898, Pola; p. 1086-1092.

[35] Heinz Nowarra: Torpedoflugzeuge; Motorbuchverlag, Stuttgart 1984, p. 8-11.

[36] Ludwig Obry: Geradlaufsteuerung für Torpedos; Behördl. Autoris. Patent – Bureau, Monath & Ehrenfest, Wien I, k.k. Privil. Archiv 45 / 1084, 9. Nov. 1894.

[37] Ludwig Obry: Geschütz Abfeuerungsapparat; Modell 1906 Beschreibung

[38] E.B. Potter: Seapower, a Naval History; USNI, Annapolis, Md. 1981, p. 128, p. 157/8.

[39] M. Schwarte: Die Technik im Weltkriege, E. S. Mittler & Sohn, Berlin 1920, p. 445-453.

[40] Egon Schwarzenberg: Contributo alla storia del silurio ideato dal fiumano Giovanni Luppis; Rivista di studi fiumani, Roma 1975.

[41] Silurificio Whitehead Sede in Fiume: La storia del siluro 1860 – 1936, Genova, Stabil. Tipogr. Alessandro Pesce, 1936 - XV

[42] Ing. Anton Stehlik: Über Torpedos; Österreichische Ingenieur u. Architektenzeitschrift, ÖIAZ, Heft 31 und 32, 1917

[43] Anthony E. Sokol: The Imperial and Royal Austro – Hungarian Navy, USNI, Annapolis, Md.1968, p. 20

[44] Torpedounterricht für die k.u.k. Kriegsmarine; Pola 1895 u. 1902, Text- u. Atlasbände

[45] Dan van der Vat: Stealth at Sea; Weidenfeld & Nicolson, London 1994, p. 19 – 22

[46] Warships, Vol. VII: D.J. Lyon: Torpedo Warfare, Conway Maritime Press Ltd., London 1983, p. 146.

[47] Hans Jürgen Witthöft: Lexikon der Deutschen Marinegeschichte, Koehlers

[48] Wörterbuch zur Deutschen Militärgeschichte; Militärverlag der D.D.R., VEB, Berlin 1985, Bd.II, p. 970-971.

[49] Privatarchiv Prof. Dieter Winkler: k.u.k. Lebenslaufblätter zu Ludwig Obry

ANEX 1

TABLE OF COMPARISON

	Luppis' Explosive Boat – "salva coste"	**Whitehead's "Fish-Torpedo"**
Dimensions:		
Length	6 m	3.4 m
Width	--	cal ϕ 35 cm
Displacement:	--	136 kg
Explosive charge:	boat filled with explosives (?)	8 kg
Design:	conservative surface vessel	revolutionary submarine craft
Hull: type material	 tarpaulin covered boat wood	 spindle-shaped with endcones boiler steel sheet
Specifications: Speed Range	 --- limited due to line guidance	 6 – 8 kn 300 m
Propulsion: engine	 clockwork (or steam engine?) 2 – bladed propeller	 compressed air, 2-cyl. engine 2 – bladed propeller
Deployment:	littoral, boat launch	on the high seas, tube launched
Perturbations:	exposed to wind and sea	undisturbed
Operations:	vessel and operator are vulnerably exposed	no further contact, stealth target approach
Target acquisition:	2-dimensional	3-dimensional
Guidance:	2 lines on double-rudders adjustable course	launch tube guided preset course > autonomous
Ignition / Detonation:	4 spars with percussion fuses at waterline	pistol fuse at tip subaquatic

ANEX 2

A Survey of the Torpedo Development
in the Imperial (and) Royal Austro-Hungarian Navy until 1915

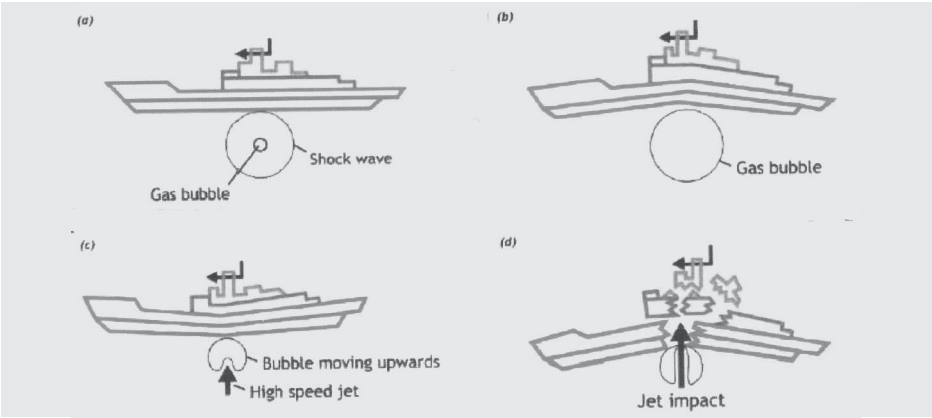
Period	**Caliber**	**Length**	**Displa-cement**	**Explosive Charge**	**Tank Pressure**	**Speed**	**Active Distance**
	[ϕ cm]	[cm]	[kg]	[kg]	[atm]	[kn]	[sm]
1867/68	35	3.35	136	20 / 30	25 / 35	6 – 7	600
1868	enhancement of depth control through augmentation of hydrostatic valve as Whitehead's "Secret"						
1873	35	5.80			70	17	760
1875/77	introduction of servomotors and of twin contra- rotating propellers for course improvement, depth regulator installed behind air tank						
1878	35	4.40	250	17	70	19.5	400
1883	Dr. R. E. Froude improves speed and warload by introducing a blunt torpedo nose						
1886	35	4.50	265	45	85	24	600
1892	45	4.0	410	90	90	26	800
1896	45	5.0	520	60	100	27	1000
1901	Dec.1896 the first torpedoes with Obry's directional control are ordered. Originally equipped with a pre-tensioned spring mechanism, the gyroscope's running time was increased from a duration of 5 to 10 min by an airjet / turbine drive in1910						
1901	General conversion to ϕ 45 cm caliber in the k.u.k. Navy and increase of tank pressure to 150 atm.						
1902	Angular presetting of course						
1907	Introduction of a heating system developed by Lt. Com. Gesztesy; from 1910 on the Whitehead torpedoes are furnished with an Armstrong – heater, by which a speed-increase of up. to 15% is obtained. From 1907 onwards even the launching tubes receive a heating system to prevent icing of the fuse tips.						
1909	Whitehead starts the manufacture of cal ϕ 53 cm ; L / 6.3 m torpedoes for the capital ships of the "Tegetthoff "– class on suggestion of the MTK, production of air borne torpedoes in 1913						
1914/15	The torpedoes in service of the k.u.k. Kriegsmarine have the subsequent specifications:						
	45	5.25	744	130	150	40	1500
						38	2000
	53	6.30	1336	180 / 213	175	36	6000
						29	10000
	53	7.18	1590	180	175	as the ϕ 53 cm ; L / 6.3m torpedo	
	limits of tolerance of the cal ϕ 45 cm torpedo: depth ± 0.8 m, lateral ±15 m at 1500 m and ± 20 m at 2000 m distance						
	The capital ships of the "Tegetthoff"-class as also the fast cruisers were equipped with cal ϕ 53 cm launching tubes with annular adapters and guiding rails to fit the launch of the cal ϕ 45 cm weapon.						

(REF.: Franz Bilzer: Die Torpedoboote der k.u.k. Kriegsmarine 1875 – 1918, Graz 1084; Edwin Gray: The Devil's Device)

ANEX 3

THE PHENOMENON OF THE UNDERWATER EXPLOSION AND THE DEVASTATING EFFECT OF THE STAND-OFF HIT

As the torpedo strikes below the waterline it hits the weaker and unprotected construction of the hull. Because of the insulating effect of the water, the subaquatic explosions are more severe than those in atmospheric ambient. Therefore explosives of higher energy density but of less brisance are employed. The direct effect of the hit is tearing the hull open, affects local destruction through pressure- and detonation waves, leading to water ingress, destabilization and deterioration of the longitudinal strength up. to its collapse.



■ *The underwater explosion beneath a ship's keel according to the "bubble theory" by Prof. Khoo* [25]

At the instant of a subaquatic explosion a shockwave will propagate within milliseconds through the water. The shockwave affects the first destructive impact on the ship's hull (Figure a). In the epicenter of the explosion a gas bubble will be generated, which under high pressure very quickly will expand to its maximum volume. The hull will be lifted, it is bent upwards and thereby its keel is weakening (Figure b).

At attaining its maximum the bubble will collapse due to its inertia. Its pressure will decline against the ambient and produce suction, thus bending the ship's body downwards (Figure c).

During the phase of collapse the bubble is attracted towards the hull. In this final phase a jet of high performance is generated, which penetrates the hull. This process (Figure d) represents the most devastating factor of the underwater explosion. The bubble is contracting and the previous process under diminishing expansion- and implosion energy is repeated oscillatingly. Its destructive energy is accordingly declining.

(Ref.: Prof. B.C. Khoo, University of Singapore)

Sažetak

U vrijeme dok je francuska mornarica napadala sjeverni Jadran i Kvarner, austrijski je kemičar/mehaničar Franz Pfeifer 1859. upoznao austrijski admiralitet s idejom o priobalnom brodu bez ljudske posade.

Godine 1864. carski je zapovjednik (Fregattenkapitän) Giovanni Luppis (1813.–1875.), rođeni Riječanin, razvio i sastavio model samohodnog (koji pokreće opruga), eksplozivnog broda Salvacoste. *Iako konvencionalna dizajna koji je sadržavao ono što je tada bilo moguće, značio je tehničko rješenje čiji su principi bili u upotrebi i u Drugome svjetskom ratu. Zbog bitnih dizajnerskih nedostataka, austrijske su pomorske vlasti zatražile od domišljata engleskog inženjera i industrijalca Roberta Whiteheada (1823.–1905.) u Rijeci, gdje je njegova kompanija STF radila pod vladinim ugovorima, da surađuje s Luppisom. Na Luppisov očaj, oružje koje je stvoreno uvelike se razlikovalo od njegova originalnog koncepta. Tako je 1866. objelodanjen "Whiteheadov riba-torpedo". Bilo je to u potpunosti uronjivo, samohodno i neprimjetno oružje koje je trebalo zadati smrtonosni udar u trbuh neprijateljskog broda. Regulacija dubine osigurana je karakterističnom inventivnošću zvanom "Whiteheadova tajna". Bočna stabilizacija preko lansirajućeg cilindra i stabilizirajućih klipova pokazala se neprikladnom za duži domet, što je poboljšano 1872. jednoosovinskim kontrarotirajućim propelerima.*

Torpedo je revolucionirao ratnu mornaricu – utjecao je na nove tipove brodova i njihovu konstrukciju, nove načine razmišljanja i ratnih taktika. Nikakvi patenti nisu primijenjeni za zaštitu ovoga izuma i mornarica se odrekla bilo kakvih prava. Tako su torpeda, ali i dozvole za njihovu proizvodnju, prodavana svim mornaricama svijeta. No glavna se proizvodnja zbivala u Whiteheadovim postrojenjima u Rijeci pa je ovaj borbeni i rastući grad postao kolijevka torpeda. Ipak, austrougarskoj su mornarici sljedećih godina njezini suparnici oduzeli tehnološko vodstvo.

Godine 1894. Tršćanin Ludwig Obry (1852.–1942.), mornarički projektant, patentirao je svoj domišljati Geradlaufsteuerung kojim je primijenio i prilagodio Foucaultov (1819.–1868.) princip žiroskopa navigacijskom upravljanju torpedom, da bi stabilizirao bočni smjer torpeda prema njegovoj meti. Žiroskop koristi činjenicu da brzo-okrećući rotor zadržava svoju osovinu mirnom čak i kada mu je podloga nemirna.

To je dovelo do revolucije u ratnoj mornarici, kao i do velikih poslova za cijelu riječku regiju. Torpedo je postao neovisan o kretnjama uzrokovanim lansiranjem i morem pa je zadržana iznimna preciznost i tajnost, i bočno i dubinski, kod dužih raspona. Vođeni projektil i moderni torpedo postupno su, nakon Drugoga svjetskog rata doveli do pomrčine teško naoružanog broda.

Sa svim svojim instrumentima, mehanizmima, senzorima, napravama i propulzijom, torpedo ne samo da je bio najopasnije oružje na moru, nego i najsloženiji mehanički sustav 19. stoljeća. Čak ni danas glavni dizajn nije bitno promijenjen. Moderna je tehnologija poboljšala bojovne glave, senzore, naprave, propulziju i lansiranje, čime je povećala vjerojatnost pogotka i smrtnosti pri većim brzinama i dužem rasponu.

Razvoj Obryjeva žiroskopa još uvijek ima golemo djelovanje na sva tehnička sredstva koja se moraju osloniti na kretnju i stabilizirani kurs u nemirnim okruženjima kao što su voda, zrak, prostor ili neravni teren. Primjer je žiroskop.

S druge strane, razvojem torpeda i nestajanjem poslovanja, industrijski se pogoni u Rijeci nisu više mogli održavati. Riječka tvornica torpeda, kolijevka torpeda i centar inženjerskog poduzetništva, ogoljena je do ruševnog stanja i danas je samo prostor industrijske arheologije.